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Optimization of PID Controller based on PSOGSA for an Automatic Voltage Regulator System

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Abstract

This paper presents an optimal Proportional Integral Derivate (PID) controller design for an Automatic Voltage Regulator (AVR) system using a new hybrid devised from the Particle Swarm Optimization and the Gravitational Search Algorithm (PSOGSA). The transient response analysis and bode analysis were considered to show the effectiveness of the design technique. Moreover, the comparison of the results between the proposed approach and other techniques such as the Ziegler-Nichols (ZN) tuning method, the Particle Swarm Optimization (PSO) tuning method and the Many Optimizing Liaisons (MOL) tuning method have been given. According to the analysis, the proposed PSOGSA algorithm gives better results than other techniques for the AVR system.

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Keywords: Automatic Voltage Regulator, Particle Swarms Optimization and Gravitational Search Algorithm, PID Controller.

1. Introduction

The Automatic Voltage Regulator (AVR) system is widely applied in power system networks, that is usually used for improving power quality and eliminating relevant issues for the electric power systems. However, the AVR system has problems with inefficient oscillated transient response, a maximum overshoot, steady-state errors. These problems can be solved by creating a closed loop system with the AVR system and the controller.

Currently, there are various controllers that can be used. However, one of the controller that is very simple and effective is the Proportional Integral Derivate (PID) controller. The advantage of a PID controller is that it can provide the robust performance for a wide range of operating conditions. It can also reduce the dynamic range error, eliminate

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the steady-state error and improve in the transient response of loop back functions system. However, for the best results, some techniques need to be implemented for PID gains to converge so that the system is optimal.

The Particle Swarm Optimization and Gravitational Search Algorithm (PSOGSA) method can solve the optimization problems of the PID controller. The PSOGSA is a low level co-evolutionary heterogeneous hybrid technique of the Particle Swarm Optimization (PSO) work together with the Gravitational Search Algorithm (GSA). This algorithm was motivated by merging social thinking ability in the PSO and the ability of local search in the GSA for a faster convergence speed and a better searching capability for a global optimum.

The objective of this paper is to implement a PSOGSA for searching optimal parameters on the PID controller for the AVR system. A desired peak amplitude, settling time, rise time and peak time are obtained by minimizing the objective function which is the Integral Time multiplied by the Absolute Error (ITAE). The result is then compared with the result of the Ziegler-Nichols (ZN), the Particle Swarm Optimization (PSO) and the Many Optimizing Liaisons (MOL) tuning method[1] to show that proposed algorithm gives better than other techniques.

2. Mathematical Modeling of an AVR System

The AVR system has the function to improve the quality of the electrical power by maintaining the terminal voltage output of the generator at a desired level. When the terminal voltage output has an error voltage occurrence, a sensor will detect and compare the error with a reference voltage for the error difference. It is then amplified by an amplifier and is used to control the generator with an exciter[2]. A simple linearized AVR system model consists of amplifier, exciter, generator and sensor. The transfer function of the AVR system given by:

$$\frac{\Delta V_t(s)}{\Delta V_{ref}(s)} = \frac{0.1s+10}{0.0004s^4+0.0454s^3+0.555s^2+1.51s+11} \tag{1}$$

This system has a peak amplitude of 1.5 volts or in other words is a maximum overshoot of 65.4%, a rise time of 0.261 seconds, a settling time of 6.970 seconds and a steady-state at 0.909.

3. Overview of Particle Swarm Optimization and Gravitational Search Algorithm

The PSOGSA This algorithm was hybridized from the Particle Swarm Optimization (PSO) and the Gravitational Search Algorithm (GSA). It was proposed by Seyedali Mirjalili and Siti Zaiton Mohd Hashim in 2010. They are used in parallel to find the optimal result[3]. The PSOGSA steps are as specified below.

Step 1: Initialization of the agent's random positions.

$$X_i = (x_i^1, \ldots x_i^d, \ldots x_i^n) \qquad ;\, for\;\; i = 1, 2, \ldots N \tag{2}$$

where x_i^d represents the position of the agent i in the d dimension while n is the space dimension.

Step 2: Computation of the fitness evolution for all agents with the appropriated objective function.

Step 3: Calculation of the gravitational constant, mass, force and acceleration of each agent by:

$$G(t) = G_0^{-\alpha \frac{t}{t_{\max}}} \tag{3}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{i=1}^{N} m_i(t)} \tag{4}$$

$$F_i^d(t) = G(t) \times \left(\frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t)} \right) \times \left(x_j^d(t) - x_i^d(t) \right) \tag{5}$$

$$ac_i^d(t) = \frac{F_i^d(t)}{M_i(t)} \tag{6}$$

where G_0 is the initial gravitational constant, α is the gravitational descending to control the searching accuracy in each t iteration until the maximum number of iterations $t_{\max}$, $M_i(t)$ is the mass of agent i and $m_i(t)$ is the inertia mass of agent i at iteration t, $F_i^d(t)$ is the total force acting on agent i, $M_{pi}(t)$ is the passive gravitational mass related to agent i, $M_{aj}(t)$ is the active gravitational mass related to agent j, $R_{ij}(t)$ is the distance between agents i and j, $x_i^d(t)$ and $x_j^d(t)$ are the position of the i and j agents while $ac_i^d(t)$ is the acceleration of agent i.

Step 4: Update of the agent's velocity and position by:

$$V_i(t+1) = w(t) \times V_i(t) + c_1' \times rand_1 \times ac_i(t) + c_2' \times rand_2 \times \left(g_{best} - X_i(t)\right) \tag{7}$$

$$X_i(t+1) = X_i(t) + V_i(t+1) \tag{8}$$

where c_1' is the adjustable cognitive acceleration constant, c_2' is the adjustable social acceleration constant, $rand_1$ and $rand_2$ are random variables, g_{best} is the best global solution, $w(t)$ is the inertia weighting, $X_i(t+1)$ and $V_i(t+1)$ are the updated position and velocity at the next iteration.

Step 5: The process is then repeated again beginning at *Step 2*. At the final iteration, the best fitness value is computed as the global fitness while the position of the corresponding agent at specified dimensions is computed as the global solution of that particular problem.

4. PID Controller based on PSOGSA

The PID controller in the paper has been used for decades with the AVR system. To improve the terminal voltage step response. The transfer function of the PID controller is represented by:

$$\frac{\Delta V_e(s)}{U(s)} = K_P + \frac{K_I}{s} + K_D s \tag{9}$$

where $U(s)$ is the controlled output, $\Delta V_e(s)$ is the terminal voltage error signals, K_P is the proportional gain, K_I is the integration gain, and K_D is the derivative gain. The desired controlled output of the system is to the peak voltage reference, minimal settling time and less steady-state error in the step response of the system[4]. The three term parameters of the PID controller are obtained by the PSOGSA algorithm in order to find the optimal gains[5].

Typical performance index in the time domain are the maximum overshoot, rise time, settling time, and steady-state error. The performance criteria usually considered in the control design is the Integral Time multiplied by the Absolute Error (ITAE)[6]. ITAE is an objective function which includes a time value. When the system starts, the time values is small but as time goes by the error signal will be increased too. Hence, this objective function will attempt to reduce the time accumulated error signal for a minimized performance index of the proposed PID controller. ITAE is given by:

$$ITAE = \int_0^t t\left|V_t - V_{ref}\right| dt \tag{10}$$

where V_t is the terminal voltage, V_{ref} is the reference voltage and t is the simulation time.

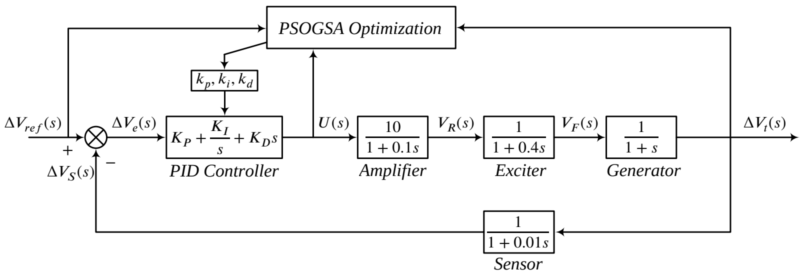

Fig. 1. Transfer function model of an AVR system with PSOGSA-PID controllers.

5. Results and Discussion

In this work, the PSOGSA algorithm converged to the optimal gain by using a swarm size of 50 units and 20 iterations. The PID controller gain of each tuning techniques is given in Table 1.

Table 1. Optimal gains obtained from ZN, PSO, MOL and PSOGSA algorithms with the results of transient response and bode analysis.

Name of tuning methods	Parameters			Peak amplitude (*V*)	Settling time (*sec*)	Rise time (*sec*)	Phase margin (*deg*)	Bandwidth (*Hz*)
	K_P	K_I	K_D					
ZN tuned	1.0800	1.9800	0.1469	1.520	2.950	0.232	51.383	7.698
PSO tuned	0.3452	0.4778	0.1017	1.143	2.561	0.536	122.678	3.364
MOL tuned	0.5523	0.4418	0.1572	1.039	1.200	0.372	151.556	5.733
PSOGSA tuned	0.4783	0.3420	0.1411	1.003	0.691	0.431	180.000	5.016

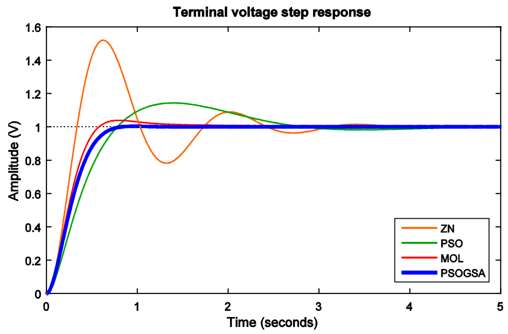

Fig. 2. The terminal voltage step response compared to PID controller tuned different techniques.

The PSOGSA tuned technique obtains a peak amplitude of 1.003 volts. In addition, the settling time of PSOGSA tuned technique is 0.691 seconds. The steady-state value of the PSOGSA tuned technique is 0.003. In the frequency response of the PSOGSA tuned system has a phase margin of 180 degrees as proof that PSOGSA tuned for AVR closed loop system has a better stability in the event of noise disturbances.

6. Conclusion

The PID controller tuning based on PSOGSA algorithm was designed for an AVR system. To prove that the PSOGSA algorithm gives the optimal solution and provides the best performance of PID controlled AVR system tuned, the terminal voltage step response was simulated for comparison. The maximum overshoots and the settling times of the controlled system which is optimized with PSOGSA algorithm are superior to other methods. In the frequency domain, analyzed using bode plots, shows the better controlled performance of PSOGSA algorithm with the maximum phase margin. Overall, the results of the PSOGSA algorithm outputs are better performance.

References

1. Panda S, BK Sahu, and PK Mohanty. Design and performance analysis of PID controller for an automatic voltage regulator system using simplified particle swarm optimization. *Journal of the Franklin Institute* 2012;**349**:2609–2625.
2. Femmy Nirmal J and D Jeraldin Auxillia. Adaptive PSO based Tuning of PID Controller for an Automatic Voltage Regulator System. *Circuits, Power and Computing Technologies (ICCPCT), 2013 International Conference on.* IEEE 2013:661-666.
3. Mirjalili Seyedali and Siti Zaiton Mohd Hashim. A New Hybrid PSOGSA Algorithm for Function Optimization. *Computer and Information Application (ICCIA), 2010 International Conference on.* IEEE 2010:374-377.
4. H Gozde and M Ari. Automatic Voltage Regulator (AVR) Design with Chaotic Particle Swarm Optimization. *European Conference on Artificial Intelligence* 2014:23-26.
5. Verma Tushar and Akhilesh Kumar Mishra. Comparative Study of PID and FOPID Controller Response for Automatic Voltage Regulation. *International Organization of Scientific Research* 2014;**4**:41-48.
6. Bhati Sapna and Dhiiraj Nitnawwre. Genetic Optimization Tuning of an Automatic Voltage Regulator System. *International Journal of Scientific Engineering and Technology* 2012;**1**:120-124.